X-RAY GENERATOR

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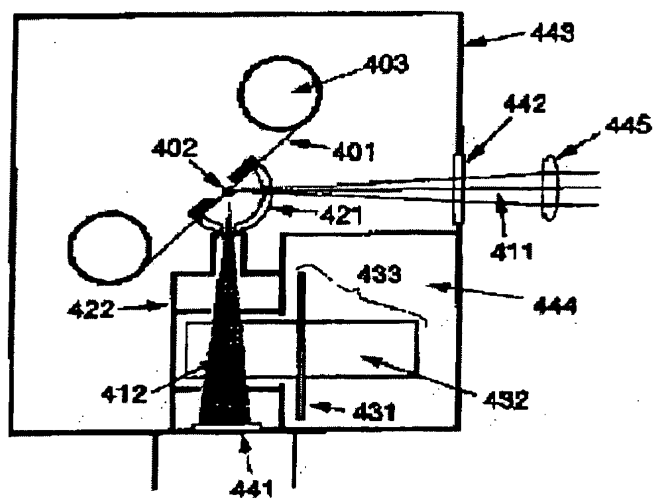
Abstract of **JP9320792**

PROBLEM TO BE SOLVED: To provide an X-ray generator using buffer gas for inhibiting scattering particles from a plasma X-ray source, capable of reducing, adhering and deposition of the scattering particles in convenient, relative to an X-ray extracting direction and capable of being used constantly for a long time as a result, even if plasma generation is long at a short time intervals. SOLUTION: An X-ray generator is constituted to irradiate a target member 401 in a pressure-reduced vacuum container 443 with an exciting energy beam 411, form a plasma 402, and extract and X-ray from the plasma 402 so that buffer gas is used to inhibit scattering particles to be radiated from the target member 401 and/or the plasma 402. In this case, the X-ray generator is provided with a scattering particle-inhibiting member 422 adjacent to or in the vicinity of a solid angle area 412, equivalent to a range in which the X-ray is to be extracted and a scattering particle dispersion inhibiting member 433, having a movable part 432 that can pass through the solid angle area 412.



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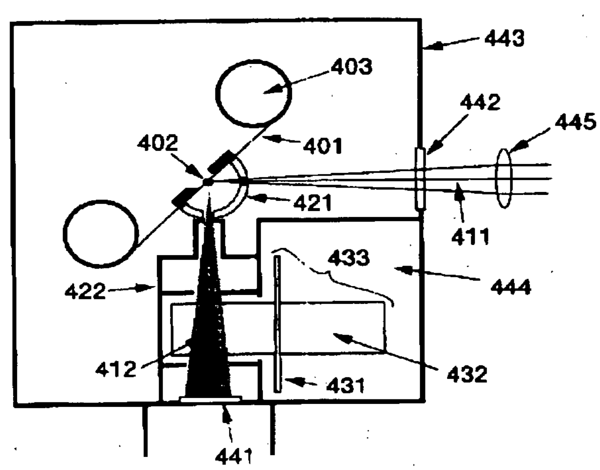
(54)【発明の名称】　Ｘ線発生装置

(57)【要約】
【課題】　プラズマＸ線源からの飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置であり、プラズマの生成が短い時間間隔で長時間にわたる場合にも、Ｘ線の取り出し方向について不都合な飛散粒子の付着、堆積を低減して、その結果、長時間安定して使用できるＸ線発生装置を提供すること。
【解決手段】　減圧された真空容器４４３内の標的部材４０１に励起エネルギービーム４１１を照射してプラズマ４０２を形成させ、該プラズマ４０２からＸ線を取り出すＸ線発生装置であり、前記標的部材４０１及び／又は前記プラズマ４０２から放出される飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置において、前記Ｘ線を取り出す範囲に相当する立体角領域４１２に隣接または近接する飛散粒子阻止部材４２２を設け、かつ、該立体角領域４１２を通過可能な可動部４３２を有する飛散粒子拡散・阻止部材４３３を設けたことを特徴とするＸ線発生装置。



【特許請求の範囲】
【請求項１】　減圧された真空容器内の標的部材に励起エネルギービームを照射してプラズマを形成させ、該プラズマからＸ線を取り出すＸ線発生装置であり、前記標的部材及び／又は前記プラズマから放出される飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置において、
前記Ｘ線を取り出す範囲に相当する立体角領域に隣接または近接する飛散粒子阻止部材を設け、かつ、該立体角領域を通過可能な可動部を有する飛散粒子拡散・阻止部材を設けたことを特徴とするＸ線発生装置。
【請求項２】　減圧された真空容器内の標的部材に励起エネルギービームを照射してプラズマを形成させ、該プラズマからＸ線を取り出すＸ線発生装置であり、前記標的部材及び／又は前記プラズマから放出される飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置において、
前記励起エネルギービームが通過する開口部と前記Ｘ線が通過する別の開口部を有する部材であり、前記標的部材及び／又は前記プラズマから放出される飛散粒子を遮蔽する飛散粒子遮蔽部材を前記標的部材及びプラズマの近傍に設け、かつ、前記Ｘ線を取り出す範囲に相当する立体角領域に隣接または近接する飛散粒子阻止部材を設け、さらに、該立体角領域を通過可能な可動部を有する飛散粒子拡散・阻止部材を設けたことを特徴とするＸ線発生装置。
【請求項３】　前記バッファガスは、前記真空容器内が所定の圧力範囲となるように導入、排出の制御がなされていることを特徴とする請求項１または２記載のＸ線発生装置。
【請求項４】　前記立体角領域内にバッファガスを導入し、かつ、該立体角領域内から飛散粒子とともにバッファガスを排出する機構をさらに設けたことを特徴とする請求項１～３記載のＸ線発生装置。
【請求項５】　前記標的部材及び／又は前記プラズマから放出される飛散粒子の放出量の方向分布を制御する飛散粒子制御部材であり、前記Ｘ線を取り出す方向への飛散粒子の放出量を低減させる飛散粒子制御部材をさらに設けたことを特徴とする請求項１～４記載のＸ線発生装置。
【請求項６】　前記飛散粒子阻止部材を冷却する冷却手段をさらに設けたことを特徴とする請求項１～５記載のＸ線発生装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、Ｘ線露光装置、Ｘ線顕微鏡、Ｘ線分析装置などのＸ線装置に用いて好適なＸ線発生装置に関するものである。
【０００２】
【従来の技術】レーザー光（励起エネルギービームの一例）を減圧された真空容器内に置かれた標的部材に集光して照射すると、標的部材は急速にプラズマ化し、このプラズマから非常に輝度の高いＸ線が輻射（放出）される（Ｘ線を発生する）ことが知られている（例えば、このようなＸ線発生源はＬＰＸ：Laser-Plasma X-raysource と呼ばれる）。
【０００３】Ｘ線の発生と共に、前記プラズマからは高速の電子やイオン等の飛散粒子が、また前記標的部材からは部材材料の飛散粒子（例えば、ガス化した材料、イオン化した材料、材料小片など）が放出されて真空容器内に飛散する（以下、これらをまとめて飛散粒子と呼ぶ）。このような飛散粒子は、清浄光学面（例えば、Ｘ線光学素子面）に衝突して、これらを破損したり、或いは付着、堆積して機能や特性を低下させたり変化させるので、大きな問題であった。
【０００４】この問題点を解決するために従来の方法では、Ｘ線源と清浄光学面との間に、Ｘ線透過性の高い物質（例えば、Ｂｅ）からなる薄膜（以下、飛散粒子阻止用薄膜またはＸ線取り出しフィルターと呼ぶ）を設置して遮蔽することにより、飛散粒子が清浄光学面に到達しないようにしていた。その他の方法としては、真空容器内にＸ線に対する透過率の高い低原子番号のガス（例えば、Ｈｅガス）を充填することにより、或いは該ガスのガス流を形成することにより、飛散粒子にガス分子を衝突させて飛散粒子の阻止を図っていた（特開昭63-292553 参照）。
【０００５】真空容器内にガスを充填した場合、プラズマや標的部材から飛び出した飛散粒子はガス分子との散乱により、飛び出したときのエネルギーをやがて失い、ガス分子の運動の中に混ざり込んでいく。そして真空容器内の部材表面や壁面に付着するか、或いは、バッファガスの導入だけでなく、排気も行っている場合には、真空ポンプによりガス分子とともに排気される。
【０００６】ところで、飛散粒子阻止用薄膜の設置により、清浄光学面への飛散粒子の付着、堆積は防げるが、そのかわり、飛散粒子阻止用薄膜上に飛散粒子が付着、堆積するので、飛散粒子阻止用薄膜のＸ線透過率が次第に低下する（Ｘ線取り出し方向における使用Ｘ線強度が低下する）という問題点がある。また、真空容器内にＸ線に対する透過率の高い低原子番号のガス（バッファガス）を充填することにより、或いは該ガスのガス流を形成することにより、飛散粒子の阻止を図る方法では、必ずしも飛散粒子を有効に阻止できるわけではないという問題点がある。
【０００７】例えば、標的部材がタンタルである場合に、十分に排気された（圧力１０Ｐａ以下）真空容器内では、飛散粒子は標的部材表面の法線方向に多く分布する。そして、真空容器内に飛散粒子阻止用のバッファガスを導入すると、飛散粒子が多く放出される方向については、ガス分子による散乱のために飛散粒子は減少する

が、散乱した飛散粒子はガス導入前には飛散粒子の放出が少なかった方向にも飛散する。

【０００８】そのため、飛散粒子を阻止するためにバッファガスを使用すると、飛散粒子の放出方向の分布が均一化される。このことは、飛散粒子の放出が少ない方向については、飛散粒子の放出が多い方向と比較してガス導入の効果が小さいか、むしろ逆効果となることを示している。Ｘ線の取り出しは、飛散粒子の放出が少ない方向において行うのが一般的であり、飛散粒子の放出が少ないＸ線の取り出し方向について、ガス導入の効果が小さいか、むしろ逆効果となることは大きな問題点である。

【０００９】特に、プラズマ近傍に飛散粒子の放出量の方向分布を制御する飛散粒子制御部材であり、前記Ｘ線を取り出す方向への飛散粒子の放出量を低減させる飛散粒子制御部材を設ける場合に、Ｘ線の取り出し方向について、ガス導入の効果が小さいか、むしろ逆効果となることは大きな問題点である。そこで、飛散粒子を阻止するためにバッファガスを使用する場合に発生する問題点を解決すべく、取り出すＸ線が通過する立体角領域を遮らないように該領域に隣接または近接して飛散粒子阻止部材を配置することにより、飛散粒子を阻止することが、本願と同一出願人により提案されている（特願平７－１２７６００）。

【００１０】

【発明が解決しようとする課題】例えば、図６に示すように、取り出すＸ線が通過する立体角領域６１２を遮らないように該領域６１２に隣接または近接して飛散粒子阻止部材６２２を設けた従来のＸ線発生装置においてバッファガスを導入した場合、プラズマ６０２の生成により発生した飛散粒子のうち、部材６２２の内側に飛び込んだものは、ガス分子との衝突によりエネルギーを失い、部材６２２の内側を漂った後、部材６２２に付着することで阻止される。

【００１１】ここで、プラズマ６０２の生成の時間間隔が長ければ、漂っている飛散粒子は、次のプラズマが生成されるまでに拡散してしまうが、プラズマが短い時間間隔で長時間にわたって発生すると、部材６２２内側の飛散粒子は十分に拡散することができないので、部材６２２の内側にガス分子と共に漂っている飛散粒子の密度が増大する。

【００１２】その結果、Ｘ線取り出し窓（清浄光学面の一例）６４１に到達・付着する飛散粒子は増加し、飛散粒子の付着によりＸ線取り出し窓６４１のＸ線透過率が低下するので、Ｘ線源として安定した利用ができないという問題点がある。即ち、このようにバッファガスを真空容器内に充填し、かつ、取り出すＸ線が通過する立体角領域に隣接または近接して飛散粒子阻止部材を設けても、プラズマの生成が短い時間間隔で長時間にわたる場合には、十分な飛散粒子の阻止効果が得られないという問題点があった。

【００１３】本発明は、かかる問題点に鑑みてなされたもので、プラズマＸ線源からの飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置であり、プラズマの生成が短い時間間隔で長時間にわたる場合にも、Ｘ線の取り出し方向について不都合な飛散粒子の付着、堆積を低減して、その結果、長時間安定して使用できるＸ線発生装置を提供することを目的とする。

【００１４】

【課題を解決する為の手段】そのため、本発明は第一に「減圧された真空容器内の標的部材に励起エネルギービームを照射してプラズマを形成させ、該プラズマからＸ線を取り出すＸ線発生装置であり、前記標的部材及び／又は前記プラズマから放出される飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置において、前記Ｘ線を取り出す範囲に相当する立体角領域に隣接または近接する飛散粒子阻止部材を設け、かつ、該立体角領域を通過可能な可動部を有する飛散粒子拡散・阻止部材を設けたことを特徴とするＸ線発生装置（請求項１）」を提供する。

【００１５】また、本発明は第二に「減圧された真空容器内の標的部材に励起エネルギービームを照射してプラズマを形成させ、該プラズマからＸ線を取り出すＸ線発生装置であり、前記標的部材及び／又は前記プラズマから放出される飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置において、前記励起エネルギービームが通過する開口部と前記Ｘ線が通過する別の開口部を有する部材であり、前記標的部材及び／又は前記プラズマから放出される飛散粒子を遮蔽する飛散粒子遮蔽部材を前記標的部材及びプラズマの近傍に設け、かつ、前記Ｘ線を取り出す範囲に相当する立体角領域に隣接または近接する飛散粒子阻止部材を設け、さらに、該立体角領域を通過可能な可動部を有する飛散粒子拡散・阻止部材を設けたことを特徴とするＸ線発生装置（請求項２）」を提供する。

【００１６】また、本発明は第三に「前記バッファガスは、前記真空容器内が所定の圧力範囲となるように導入、排出の制御がなされていることを特徴とする請求項１または２記載のＸ線発生装置（請求項３）」を提供する。また、本発明は第四に「前記立体角領域内にバッファガスを導入し、かつ、該立体角領域内から飛散粒子とともにバッファガスを排出する機構をさらに設けたことを特徴とする請求項１～３記載のＸ線発生装置（請求項４）」を提供する。

【００１７】また、本発明は第五に「前記標的部材及び／又は前記プラズマから放出される飛散粒子の放出量の方向分布を制御する飛散粒子制御部材であり、前記Ｘ線を取り出す方向への飛散粒子の放出量を低減させる飛散粒子制御部材をさらに設けたことを特徴とする請求項１～４記載のＸ線発生装置（請求項５）」を提供する。ま

た、本発明は第六に「前記飛散粒子阻止部材を冷却する冷却手段をさらに設けたことを特徴とする請求項１～５記載のＸ線発生装置（請求項６）」を提供する。
【００１８】
【発明の実施の形態】本発明のプラズマＸ線源からの飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置においては、前記Ｘ線を取り出す範囲に相当する立体角領域に隣接または近接する飛散粒子阻止部材を設け、かつ、該立体角領域を通過可能な可動部を有する部材であり、飛散粒子を拡散及び／または阻止する飛散粒子拡散・阻止部材を設けている（請求項１）。
【００１９】そのため、プラズマの生成が短い時間間隔で長時間にわたる場合にも、Ｘ線の取り出し方向について、不都合な飛散粒子の付着、堆積（飛散粒子阻止用薄膜や清浄光学面などへの付着、堆積）を低減できる。また、本発明のプラズマＸ線源からの飛散粒子を阻止するためにバッファガスを用いるＸ線発生装置においては、前記励起エネルギービームが通過する開口部と前記Ｘ線が通過する別の開口部を有する部材であり、前記標的部材及び／又は前記プラズマから放出される飛散粒子を遮蔽する飛散粒子遮蔽部材を前記標的部材及びプラズマの近傍に設け、かつ、前記Ｘ線を取り出す範囲に相当する立体角領域に隣接または近接する飛散粒子阻止部材を設け、さらに、該立体角領域を通過可能な可動部を有する部材であり、飛散粒子を拡散及び／または阻止する飛散粒子拡散・阻止部材を設けている（請求項２）。
【００２０】そのため、プラズマの生成が短い時間間隔で長時間にわたる場合にも、Ｘ線の取り出し方向について、不都合な飛散粒子の付着、堆積（飛散粒子阻止用薄膜や清浄光学面などへの付着、堆積）をさらに低減できる。ここで、前記従来の飛散粒子阻止部材の一例として、Ｘ線を取り出す範囲に相当する立体角領域の切断面に等しい（または略等しい）開孔を有する部材を該領域に隣接または近接させて設けた場合を考える。
【００２１】かかる飛散粒子阻止部材を立体角領域に隣接させて設けても、立体角領域の切断面に等しい開孔に達するＸ線には、なんら影響がなく、取り出されるＸ線の量は変化しない。これに対して、立体角領域内に進入しようとする飛散粒子は、飛散粒子阻止部材により多くが阻止されるので、Ｘ線の取り出し方向について、不都合な飛散粒子の付着、堆積を低減することができる。
【００２２】このような効果をもたらす飛散粒子阻止部材は、飛散粒子が立体角領域内に進入するのを阻止できる形状を有すればよく、開孔付きの板状の物に限定されるわけではない。また、厳密には取り出すＸ線光量が低下することになるが、Ｘ線を取り出す範囲に相当する立体角領域内に飛散粒子阻止部材を設けても、前記の効果が得られる。例えば、立体角領域内にあるＸ線の光路上に非常に薄い板を光路に沿って設ける場合である。
【００２３】ところで、前述したように、バッファガスを真空容器内に充填し、かつ、取り出すＸ線が通過する立体角領域に隣接または近接して飛散粒子阻止部材を設けても、プラズマの生成が短い時間間隔で長時間にわたる場合には、十分な飛散粒子の阻止効果が得られないという問題が発生する。そこで、本発明のＸ線発生装置においては、立体角領域を通過可能な可動部を有する部材であり、飛散粒子を拡散及び／または阻止する飛散粒子拡散・阻止部材をさらに設けることで、この問題を解決している。
【００２４】図１に本発明のＸ線発生装置（一例）にかかる各部材の配置を示す。図１に示すＸ線発生装置では、ガスが適度な圧力に充填された真空容器内にターゲット材（標的部材の一例）１０１が配置され、プラズマ１０２の発生位置の近傍には、励起エネルギービーム１１１が通過する開口部とＸ線が通過する別の開口部を有する部材であり、ターゲット材１０１及び／又はプラズマ１０２から放出された飛散粒子を遮蔽する飛散粒子遮蔽部材１２１が配置されている。
【００２５】また、Ｘ線を取り出す範囲に相当する立体角領域１１２に隣接または近接する飛散粒子阻止部材１２２が設けられ、さらに、該立体角領域を通過可能な可動部１３２を有する部材であり、飛散粒子を拡散及び／または阻止する飛散粒子拡散・阻止部材１３３が設けられている。ここで飛散粒子阻止部材１２２は、前記立体角領域１１２内に配置されたＸ線取り出し窓（清浄光学面の一例）１２３に飛散粒子が衝突、付着または堆積するのを防止するためのダクト状の部材であり、立体角領域１１２及びＸ線取り出し窓１２３を取り囲んで設けられている。
【００２６】また、飛散粒子拡散・阻止部材１３３は、図２に示すような形状（羽根２３２及び軸２３１）を有し、羽根（可動部の一例）１３２が軸１３１を回転軸として回転できるように構成されている。図１に示すＸ線発生装置では、ターゲット材１０１及び／又はプラズマ１０２から放出された飛散粒子の殆どが飛散粒子遮蔽部材１２１により遮蔽される。
【００２７】遮蔽部材１２１の開口を通過して飛散粒子阻止部材１２２の内側に進入した飛散粒子も、バッファガス分子との散乱により進行方向を変化させながらエネルギーを失い、やがてガス分子の運動の中に混ざり込んで、部材１２２の内側空間を漂う。そして、該空間を漂うこの飛散粒子は、軸１３１のまわりに回転する羽根１３３に付着し（飛散粒子阻止効果）、或いは、飛散粒子拡散・阻止部材１３３の運動によりかき出さる（飛散粒子拡散効果）ので、阻止部材１２２の内側空間の飛散粒子密度は低く保たれる。
【００２８】そして、かき出された飛散粒子は、阻止部材１２２に吸着される。即ち、部材１２２、１３３の前記作用により、或いは、部材１２１、１２２、１３３の前記作用により、Ｘ線取り出し窓１０３に到達する飛散

粒子量は、これらの部材を設けない場合と比較して大きく減少する。このように、本発明のX線発生装置によれば、プラズマの生成が短い時間間隔で長時間にわたる場合にも、X線の取り出し方向について不都合な飛散粒子の付着、堆積を低減して、その結果、長時間安定して装置を使用できる（請求項１、２）。

【００２９】本発明にかかる飛散粒子拡散・阻止部材１３３の可動部（例えば、羽根１３２）は、X線を取り出す立体角領域１１２を通過するため、X線が発生しているときに可動部が該立体角領域１１２内にあると、X線を遮って、X線の光量を低下させてしまう。そこで、X線が発生しているときには、飛散粒子拡散・阻止部材１３３の可動部が該立体角領域１１２内に存在しないように、可動部（例えば、羽根１３２）の動作（例えば、回転）の周期を制御することが好ましい。

【００３０】たとえば、部材１３３の可動部が該立体角領域１１２を通過するのは、１回のプラズマの発生ごとである必要はなく、飛散粒子阻止部材１２２の内側空間における飛散粒子の密度が高くならないうちは、数回～数十回に一度でよい。なお、ある程度のX線光量の低下を許容できる場合には、プラズマの発生時刻と部材１３３の可動（例えば、回転）周期に相関がなくてもよい。これは、プラズマの発生時刻と部材１３３の可動周期に相関がある場合には、常に同じ領域のX線が遮られてしまう可能性があるからである。

【００３１】X線露光装置など複数回のX線の照射が必要な用途ではその影響はさらに小さくなる。本発明にかかる飛散粒子拡散・阻止部材１３３の可動部（例えば、羽根１３２）は、飛散粒子拡散・阻止効果を増大させるために、X線を取り出す立体角領域１１２のうち、できるだけ広い領域（空間）を通過できることが好ましく、例えば、図3のような形状よりも図2のような形状が好ましい。

【００３２】取り出すX線の適切な光量が得られるように、或いは、適切な飛散粒子阻止効果が得られるように、本発明にかかるバッファガスは真空容器内が所定の圧力範囲となるように導入、排出の制御がなされていることが好ましい（請求項３）。本発明にかかるバッファガスは、利用する（取り出す）波長のX線に対する吸収が少ないものが好ましく、例えば、ヘリウム、酸素、チッ素、空気、アルゴン、クリプトンなどのガスのうちから、利用するX線に対する吸収が少ないものを選択すればよい。

【００３３】本発明のX線発生装置においては、X線を取り出す立体角領域内にバッファガスを導入し、かつ、該立体角領域内から飛散粒子とともにバッファガスを排出する機構をさらに設けることが好ましい（請求項４）。かかる構成にすると、バッファガスの導入によりX線を取り出す立体角領域内の飛散粒子を拡散させ、また拡散させた飛散粒子とともにバッファガスを該領域内から外側へ排出できるので、X線の取り出し方向について、不都合な飛散粒子の付着、堆積をさらに低減できる。

【００３４】本発明のX線発生装置においては、標的部材及び／又はプラズマから放出される飛散粒子の放出量の方向分布を制御する飛散粒子制御部材であり、X線を取り出す方向への飛散粒子の放出量を低減させる飛散粒子制御部材をさらに設けると、、X線の取り出し方向における飛散粒子阻止効果が増大するので好ましい（請求項５）。

【００３５】かかる飛散粒子制御部材に用いる材料としては、例えば、タンタル、タングステン、ダイヤモンド、セラミック、ステンレスなどの高融点、又は高硬度の材料が好ましい。これは、飛散粒子制御部材がプラズマに非常に近接した位置に配置されるので、プラズマから飛来するイオンや電子の該部材表面への衝突による該部材材料の放出を防止するためである。即ち、該部材材料の放出があると飛散粒子と同様に不都合な付着、堆積が生じるので、これを防止するのである。

【００３６】本発明にかかる飛散粒子阻止部材を冷却する冷却手段をさらに設けると、該部材が飛散粒子を吸着しやすくなって、阻止効果が増大するので好ましい（請求項６）。或いは、飛散粒子を吸着しやすいように、飛散粒子阻止部材の表面を加工（例えば、つや消し加工）することも好ましい。本発明にかかる標的部材の形状は、巻き取り可能なテープ状が好ましいが、板状、バルク状、円柱状、または微粒子状でもよい。また、標的部材の材料は、Ｔａ，Ｗなどが好ましい。

【００３７】以下、本発明を実施例により更に詳細に説明するが、本発明はこれらの実施例に限定されるものではない。

【００３８】

【実施例】図４に標的部材としてテープ状のタンタルを用い、波長１４ｎｍのX線を取り出して利用する本実施例のX線発生装置の概略部分構成図を示す。ＹＡＧレーザー光（励起エネルギービームの一例）４１１が、集光レンズ４４５により集光されながら入射窓４４２を透過して、真空容器４４３内に入射し、タンタルターゲット（標的部材の一例）４０１の表面に集光される。

【００３９】タンタルターゲット４０１は厚さ１５μｍのテープ形状であり、テープ上の同じ位置にレーザー光が繰り返し集光されることのないように、プラズマ発生時には、駆動手段（例えば、モーター、不図示）によりリール４０３を回転させてタンタルテープを巻き取っている。タンタルテープの移動速度は、一つのプラズマが生成されてから次のプラズマを生成するためのレーザー光が入射するまでに、プラズマ発生によりタンタルテープに生ずる孔の直径分以上にテープが移動する速度である。

【００４０】タンタルテープターゲット４０１上にＹＡ

Ｇレーザーは４５度の入射角で入射、集光され、生成したプラズマ４０２から発生したＸ線は、ＹＡＧレーザーとは反対側の４５度の方向に設けられたＸ線取り出し窓（清浄光学面の一例）４４１からＸ線光学系へと導かれる。プラズマ４０２の近傍には、ターゲット４０１に入射するＹＡＧレーザー４１１と取り出すＸ線とがそれぞれ通過できる開口を有する飛散粒子遮蔽部材４２１が設けられており、ターゲット４０１及び／又はプラズマ４０２から放出された飛散粒子の殆どがこの飛散粒子遮蔽部材４２１により遮蔽される。

【００４１】また、遮蔽部材４２１のＸ線取り出し用の開口付近からＸ線取り出し窓付近にかけて、Ｘ線を取り出す範囲に相当する立体角領域４１２に隣接または近接する飛散粒子阻止部材４２２が設けられている。ここで飛散粒子阻止部材４２２は、立体角領域４１２内に配置されたＸ線取り出し窓４４１に飛散粒子が衝突、付着または堆積するのを防止するためのダクト状の部材であり、立体角領域４１２及びＸ線取り出し窓４４１を取り囲んで設けられている。

【００４２】真空容器４４３内にはバッファガスとしてＫｒガスが導入されると同時に排気されており、0.1 Ｔｏｒｒの圧力を保つように制御されている。Ｋｒガスは、波長１４ｎｍのＸ線に対して同じ圧力ではＨｅと同程度の透過率を有する。前記遮蔽部材４２１により遮蔽されず、その開口を通過して飛散粒子阻止部材４２２の内側に進入した飛散粒子も、バッファガス分子との散乱により進行方向を変化させながらエネルギーを失い、やがてガス分子の運動の中に混ざり込んで、部材４２２の内側空間を漂う。

【００４３】そして、部材４２２の内側空間に隣接する空間４４４には、立体角領域４１２を通過可能な羽根（可動部の一例）４３２を有する部材であり、飛散粒子を拡散及び／または阻止する飛散粒子拡散・阻止部材４３３が設けられている。部材４３３は図２に示すような形状をしており、軸４３１のまわりに真空中で羽根４３２が回転する機構（不図示）を備えている。

【００４４】プラズマ４０２は繰り返し周波数１０Ｈｚで発生しており、部材４３３の羽根４３２は軸４３１を回転軸として１秒間に５回転する。部材４３３は２枚の羽根４３２を有しており、一つのプラズマが生成されてから次のプラズマが生成されるまでの間に、Ｘ線を取り出す前記立体角領域４１２を羽根４３２が通過することになる。

【００４５】ここで、ＹＡＧレーザー４１１の発振のタイミングは、部材４３３の羽根４３２の位置と相関を持って制御されており、羽根４３２がＸ線を遮る位置（立体角領域内）にある時にはプラズマを発生させないように制御されている。ガス分子との散乱によりエネルギーを失って部材４２２の内側空間に漂う飛散粒子は、軸４３１のまわりに回転する羽根４３２に付着し（飛散粒子阻止効果）、或いは、回転する羽根４３２によりかき出さる（飛散粒子拡散効果）ので、部材４２２の内側空間の飛散粒子密度は低く保たれる。

【００４６】部材４３３が設けられた空間４４４及び飛散粒子阻止部材４２２の内側空間では、真空容器４４３全体とは別にＫｒガスの導入と排気がなされているので、回転する羽根４３２によりかき出された飛散粒子は速やかに拡散して阻止部材４２２に吸着する。そのため、Ｘ線取り出し窓４４１に到達する飛散粒子量は、著しく減少する。

【００４７】このように、本実施例のＸ線発生装置によれば、プラズマの生成が短い時間間隔で長時間にわたる場合にも、Ｘ線の取り出し方向について不都合な飛散粒子の付着、堆積を低減して、その結果、長時間安定して装置を使用できる。本実施例では、部材４３３を図２のような形状とし、１秒間に軸回りに５回転することとしたが、その形状、運動の速度はこれに限るものではない。

【００４８】また、羽根の数も一対（２枚）に限定されるものではなく、図５に示すように、複数対の羽根を有する飛散粒子拡散・阻止部材５３３により、各対の羽根が位置する各空間の飛散粒子密度の低下を図ってもよい。

【００４９】

【発明の効果】以上、説明したように、本発明のＸ線発生装置によれば、プラズマの生成が短い時間間隔で長時間にわたる場合にも、Ｘ線の取り出し方向について不都合な飛散粒子の付着、堆積を低減して、その結果、長時間安定して装置を使用できる。

【図面の簡単な説明】

【図１】は、本発明のＸ線発生装置（一例）にかかる各部材を示す概略構成図である。

【図２】は、本発明にかかる飛散粒子拡散・阻止部材の一例を示す概略斜視図である。

【図３】は、本発明にかかる飛散粒子拡散・阻止部材として好ましくない形状の例を示す概略斜視図である。

【図４】は、実施例にかかるＸ線発生装置の概略構成図である。

【図５】は、別の実施例にかかるＸ線発生装置の概略構成図である。

【図６】は、従来のＸ線発生装置の概略構成図である。

【符号の説明】

１０１，４０１，５０１，６０１　標的部材

１０２，４０２，５０２，６０２　プラズマ

１１１，４１１，５１１，６１１　励起レーザー光（励起エネルギービームの一例）

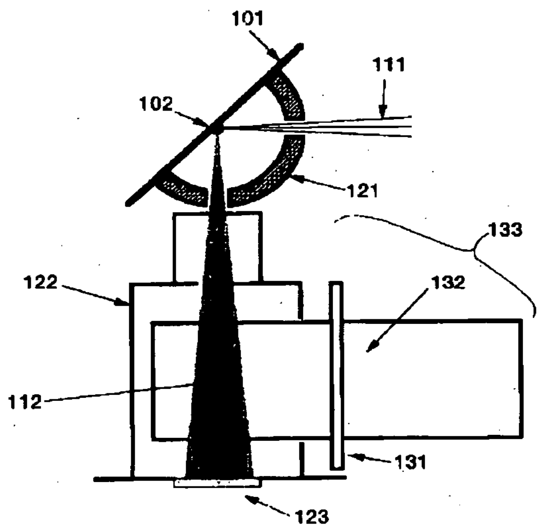
１１２，４１２，５１２，６１２　Ｘ線を取り出す範囲に相当する立体角領域

１２１，４２１，５２１，６２１　飛散粒子遮蔽部材

１２２，４２２，５２２，６２２　飛散粒子阻止部材

１３１，２３１，３３１，４３１，５３１　軸（飛散粒子拡散・阻止部材の構成要素の一例）
１３２，２３２，３３２，４３２，５３２　羽根（飛散粒子拡散・阻止部材の可動部の一例）
１３３，４３３，５３３　飛散粒子拡散・阻止部材
１２３，４４１，５４１，６４１　Ｘ線取り出し窓（清浄光学面の一例）
４４２，５４２，６４２　入射窓
４４３，５４３，６４３　真空容器
４４４，５４４　飛散粒子阻止部材の内側空間に隣接する空間
４４５，５４５，６４５　ＹＡＧレーザー集光レンズ
以　上

【図１】



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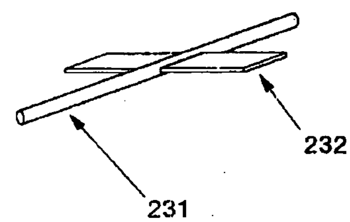

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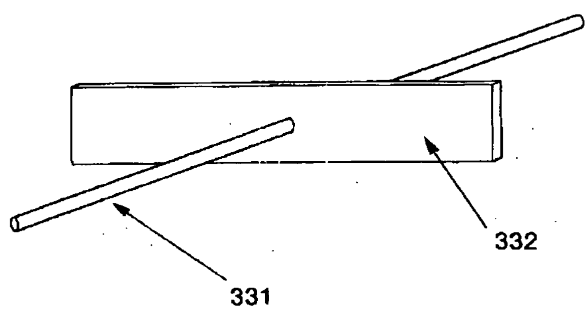

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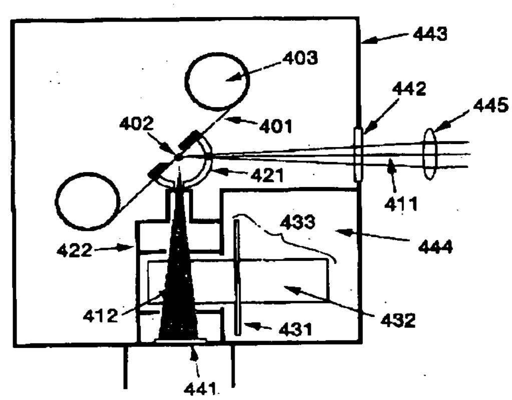

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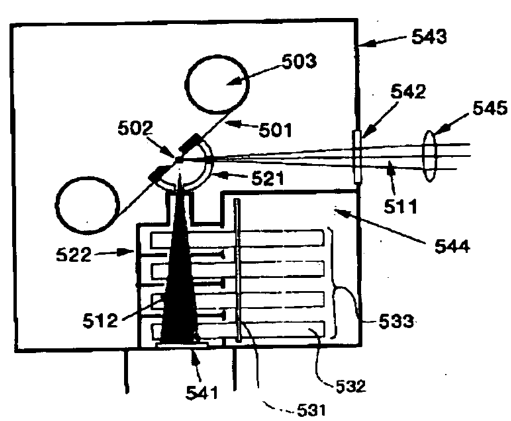

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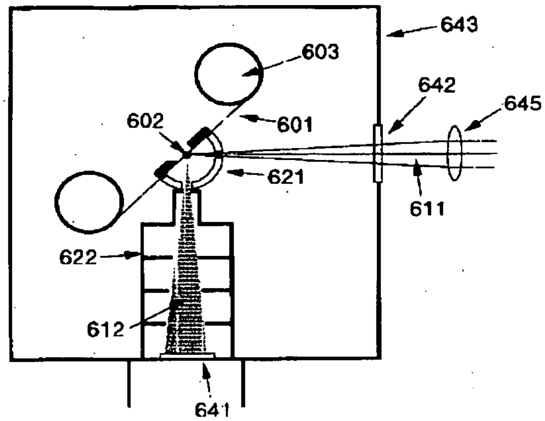

[Title of the Invention] X-RAY GENERATOR

[ABSTRACT]

[Problem] To provide an X-ray generator using a buffer gas for inhibiting scattered particles from a plasma X-ray source, capable of reducing inconvenient adhesion and deposition of the scattered particles with respect to an X-ray extracting direction, and capable of being used stably for a long time as a result, even if plasmas are generated at short time intervals for a long time.

[Solution Means] An X-ray generator is constituted to irradiate a target member 401 in a pressure-reduced vacuum container 443 with an exciting energy beam 411, form a plasma 402, and extract an X-ray from the plasma 402 so that a buffer gas is used to inhibit scattered particles released from the target member 401 and/or the plasma 402. In this case, the X-ray generator is provided with: a scattered particle inhibiting member 422 disposed adjacent to or in the vicinity of a solid angle area 412 corresponding to a region in which the X-ray is extracted; and a scattered particle diffusing and inhibiting member 433 having a movable part 432 that can pass through the solid angle area 412.

[CLAIMS]

[Claim 1] An X-ray generator which irradiates a target member in a pressure-reduced vacuum container with an exciting energy beam to form a plasma and extract an X-ray

from the plasma and which uses a buffer gas for inhibiting scattered particles released from the target member and/or the plasma, the X-ray generator comprising:

a scattered particle inhibiting member disposed adjacent to or in the vicinity of a solid angle area corresponding to a region in which the X-ray is extracted; and

a scattered particle diffusing and inhibiting member having a movable part that can pass through the solid angle area.

[Claim 2] An X-ray generator which irradiates a target member in a pressure-reduced vacuum container with an exciting energy beam to form a plasma and extract an X-ray from the plasma and which uses a buffer gas for inhibiting scattered particles released from the target member and/or the plasma, the X-ray generator comprising:

a scattered particle intercepting member which has an opening to pass the exciting energy beam and another opening to pass the X-ray and which intercepts the scattered particles released from the target member and/or the plasma and which is disposed in the vicinity of the target member and the plasma;

a scattered particle inhibiting member disposed adjacent to or in the vicinity of a solid angle area corresponding to a region in which the X-ray is extracted; and

a scattered particle diffusing and inhibiting

member having a movable part that can pass through the solid angle area.

[Claim 3] The X-ray generator according to claim 1 or 2, wherein introducing and discharging of the buffer gas are controlled so as to bring the inside of the vacuum container into a predetermined pressure range.

[Claim 4] The X-ray generator according to claims 1 to 3, further comprising:

a mechanism which introduces the buffer gas into the solid angle area and which discharges the buffer gas together with the scattered particles from the solid angle area.

[Claim 5] The X-ray generator according to claims 1 to 4, further comprising:

a scattered particle control member which controls a direction distribution of a release amount of the scattered particles released from the target member and/or the plasma and which reduces the release amount of the scattered particles in the direction in which the X-ray is extracted.

[Claim 6] The X-ray generator according to claims 1 to 5, further comprising:

cooling means for cooling the scattered particle inhibiting member.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention] The present invention

relates to an X-ray generator suitable for use in X-ray devices such as an X-ray generator exposure device, an X-ray generator microscope, and an X-ray analysis device.

[0002]

[Related Art] It is known that when a target member disposed in a pressure-reduced vacuum container is irradiated with condensed laser light (one example of an exciting energy beam), the target member is rapidly formed into a plasma, and an X-ray having a very high luminance is radiated (released) from this plasma (the X-ray is generated) (such X-ray source is referred to as, e.g., a laser-plasma X-ray source (LPX)).

[0003] When the X-ray is generated, the plasma releases scattered particles such as high-speed electrons and ions, and the target member releases scattered particles (e.g., a gasified material, an ionized material, material small pieces, etc.) of a member material. The particles fly and scatter in the vacuum container (these will be hereinafter collectively referred to as the scattered particles). Such scattered particles collide with a clean optical face (e.g., X-ray optical element face) to break the face. Alternatively, the particles are attached or deposited to deteriorate or change functions or characteristics of the face. They have been large problems.

[0004] To solve the problems, in a conventional method, a thin film (hereinafter referred to as the scattered particle inhibiting thin film or the X-ray extracting

filter) constituted of a substance (e.g., Be) having a high X-ray transmittance) is disposed between the X-ray source and the clean optical face. Accordingly, the scattered particles have been intercepted and prevented from reaching the clean optical face. As another method, the vacuum container is filled with a gas having a high X-ray transmittance and a small atomic number (e.g., an He gas), or a flow of the gas is formed in the container. Accordingly, the scattered particles are allowed to collide with gas molecules, and inhibited (see Japanese Patent Application Laid-Open No. 63-292553).

[0005] In a case where the vacuum container is filled with the gas, the scattered particles that have flown out of the plasma or the target member scatter together with the gas molecules, finally lose flying energy, and come into movement of the gas molecules. Moreover, the particles are attached to member surfaces in the vacuum container, and container wall faces. Alternatively, when the buffer gas is not only introduced but also discharged, the particles are discharged together with the gas molecules via a vacuum pump.

[0006] In addition, when the thin film for inhibiting the scattered particles is disposed, the particles can be prevented from being attached or deposited onto the clean optical face, but instead the scattered particles are attached or deposited onto the thin film for inhibiting the scattered particles. Therefore, there is a problem that X-

ray transmittance of the thin film for inhibiting the scattered particles gradually lowers (intensity of the X-ray for use in the X-ray extracting direction lowers). In the method of filling the vacuum container with the gas (buffer gas) having the high X-ray transmittance and small atomic number or forming the flow of the gas to inhibit the scattered particles, there is a problem that the scattered particles cannot be necessarily effectively inhibited.

[0007] For example, when the target member is tantalum, many scattered particles are distributed in a direction of the normal to the target member surface in the sufficiently exhausted vacuum container (pressure of 10 Pa or less). Moreover, when the buffer gas for inhibiting the scattered particles is introduced into the vacuum container, the scattered particles are reduced owing to the scattering due to the gas molecule in a direction in which many scattered particles are released, but the scattered particles also fly and scatter in a direction in which few scattered particles are released before the gas is introduced.

[0008] Therefore, when the buffer gas is used to inhibit the scattered particles, a distribution of the release directions of the scattered particles is homogenized. This indicates that an effect obtained by introducing the gas is small or rather an opposite effect is exerted in the direction in which less scattered particles are released as compared with the direction in which more scattered particles are released. In general, the X-ray is extracted

in the direction in which less scattered particles are released. There is a large problem that the gas introducing effect is small or rather the opposite effect results in the X-ray extracting direction in which less scattered particles are released.

[0009] Especially, in a case where in the vicinity of the plasma there is disposed a scattered particle control member which controls the direction distribution of the release amount of the scattered particles and which reduces the release amount of the scattered particles in the X-ray extracting direction, there is a large problem that the gas introducing effect is small or rather the opposite effect results in the X-ray extracting direction. To solve the problem generated in a case where the buffer gas is used to inhibit the scattered particles, the present applicant has proposed that a scattered particle inhibiting member be disposed adjacent to or in the vicinity of a solid angle area that passes the extracted X-ray so as not to intercept the area, thereby inhibiting the scattered particles (Japanese Patent Application No. 7-127600).

[0010]

[Problem to be solved by the Invention] For example, as shown in FIG. 6, in a case where the buffer gas is introduced into a conventional X-ray generator in which a scattered particle inhibiting member 622 is disposed adjacent to or in the vicinity of a solid angle area 612 that passes the extracted X-ray so as not to intercept the

area, among the scattered particles generated by generating a plasma 602, the particles that have flown into the member 622 lose energy when they collide with the gas molecules. The particles float in the member 622 and thereafter stick to the member 622. Thus, the particles are inhibited.

[0011] Here, when a generation time interval of the plasma 602 is long, the floating scattered particles are diffused until the next plasma is generated. However, if the plasmas are generated at short time intervals for a long time, the scattered particles cannot be sufficiently diffused in the member 622. This results in an increase of density of the scattered particles floating together with the gas molecules in the member 622.

[0012] As a result, the scattered particles reaching and sticking to an X-ray extracting window (one example of the clean optical face) increase, and the X-ray transmittance of the X-ray extracting window 641 lowers owing to the attached scattered particles. Therefore, there is a problem that the X-ray source cannot be stably utilized. That is, even in a case where the vacuum container is filled with the buffer gas in this manner, and the scattered particle inhibiting member is disposed adjacent to or in the vicinity of the solid angle area that passes the extracted X-ray, when the plasmas are generated for a long time at short intervals, there is a problem that it is not possible to obtain a sufficient scattered particle inhibiting effect.

[0013] The present invention has been developed in view of such problem, and an object thereof is to provide an X-ray generator which uses a buffer gas for inhibiting scattered particles from a plasma X-ray source and which reduces inconvenient attachment and deposition of the scattered particles with respect to an X-ray extracting direction and which can be used stably for a long time as a result, even if plasmas are generated at short time intervals for a long time.

[0014]

[Means for solving the Problem] To this end, the present invention first provides "an X-ray generator which irradiates a target member in a pressure-reduced vacuum container with an exciting energy beam to form a plasma and extract an X-ray from the plasma and which uses a buffer gas for inhibiting scattered particles released from the target member and/or the plasma, the X-ray generator comprising: a scattered particle inhibiting member disposed adjacent to or in the vicinity of a solid angle area corresponding to a region in which the X-ray is extracted; and a scattered particle diffusing and inhibiting member having a movable part that can pass through the solid angle area (claim 1)".

[0015] Moreover, the present invention secondly provides "an X-ray generator which irradiates a target member in a pressure-reduced vacuum container with an exciting energy beam to form a plasma and extract an X-ray from the plasma

and which uses a buffer gas for inhibiting scattered particles released from the target member and/or the plasma, the X-ray generator comprising: a scattered particle intercepting member which has an opening to pass the exciting energy beam and another opening to pass the X-ray and which intercepts the scattered particles released from the target member and/or the plasma and which is disposed in the vicinity of the target member and the plasma; a scattered particle inhibiting member disposed adjacent to or in the vicinity of a solid angle area corresponding to a region in which the X-ray is extracted; and a scattered particle diffusing and inhibiting member having a movable part that can pass through the solid angle area (claim 2)".

[0016] Furthermore, the present invention thirdly provides "the X-ray generator according to claim 1 or 2, wherein introducing and discharging of the buffer gas are controlled so as to bring the inside of the vacuum container into a predetermined pressure range (claim 3)". The present invention fourthly provides "the X-ray generator according to claims 1 to 3, further comprising: a mechanism which introduces the buffer gas into the solid angle area and which discharges the buffer gas together with the scattered particles from the solid angle area (claim 4)".

[0017] Additionally, the present invention fifthly provides "the X-ray generator according to claims 1 to 4, further comprising: a scattered particle control member

which controls a direction distribution of a release amount of the scattered particles released from the target member and/or the plasma and which reduces the release amount of the scattered particles in the direction in which the X-ray is extracted (claim 5)". The present invention sixthly provides "the X-ray generator according to claims 1 to 5, further comprising: cooling means for cooling the scattered particle inhibiting member (claim 6)".

[0018]

[Mode for carrying out the Invention] In an X-ray generator of the present invention which uses a buffer gas for inhibiting scattered particles from a plasma X-ray source, a scattered particle inhibiting member is disposed adjacent to or in the vicinity of a solid angle area corresponding to a region in which the X-ray is extracted. Moreover, there is disposed a scattered particle diffusing and inhibiting member which has a movable part that can pass through the solid angle area and which diffuses and/or inhibits the scattered particles (claim 1).

[0019] Therefore, even when the plasmas are generated at short time intervals for a long time, it is possible to reduce inconvenient attachment and deposition (attachment and deposition onto a thin film for inhibiting the scattered particles, a clean optical face or the like) of the scattered particles in the X-ray extracting direction. In the X-ray generator which uses the buffer gas for inhibiting the scattered particles from the plasma X-ray

source, in the vicinity of the target member and the plasma, there is disposed a scattered particle intercepting member which has an opening to pass the exciting energy beam and another opening to pass the X-ray and which intercepts the scattered particles released from the target member and/or the plasma. Furthermore, a scattered particle inhibiting member is disposed adjacent to or in the vicinity of a solid angle area corresponding to a region in which the X-ray is extracted. In addition, there is disposed a scattered particle diffusing and inhibiting member which has a movable part that can pass through the solid angle area and which diffuses and/or inhibits the scattered particles (claim 2).

[0020] Therefore, even when the plasmas are generated at the short time intervals for a long time, it is possible to further reduce the inconvenient attachment and deposition (attachment and deposition onto the thin film for inhibiting the scattered particles, the clean optical face or the like) of the scattered particles in the X-ray extracting direction. Here, there is considered a case where as one example of a conventional scattered particle inhibiting member, a member is disposed adjacent to or in the vicinity of the solid angle area, the member having an open hole equivalent to (or substantially equivalent to) a cross-sectional face of the solid angle area corresponding to the region in which the X-ray is extracted.

[0021] Even when such scattered particle inhibiting

member is disposed adjacent to the solid angle area, there is not any influence on the X-ray reaching the open hole equivalent to the cross-sectional face of the solid angle area, and an amount of the extracted X-ray does not change. On the other hand, the scattered particles which are to enter the solid angle area are more inhibited by the scattered particle inhibiting member. Therefore, it is possible to reduce the inconvenient attachment and deposition of the scattered particles in the X-ray extracting direction.

[0022] The scattered particle inhibiting member which brings such effects may have such a shape as to prevent the scattered particles from entering the solid angle area, and the member is not limited to a plate-shaped member having the open hole. Strictly, the light quantity of the extracted X-ray lowers, but the above-described effects can be obtained even when the scattered particle inhibiting member is disposed in the solid angle area corresponding to the region in which the X-ray is extracted. For example, a very thin plate may be disposed along an optical path of the X-ray in the solid angle area.

[0023] In addition, as described above, even in a case where the vacuum container is filled with the buffer gas, and the scattered particle inhibiting member is disposed adjacent to or in the vicinity of the solid angle area that passes the extracted X-ray, when the plasmas are generated at the short time intervals for the long time, a problem

occurs that a sufficient scattered particle inhibiting effect cannot be obtained. Therefore, in the X-ray generator of the present invention, this problem is solved by further disposing the scattered particle diffusing and inhibiting member which has the movable part capable of passing the solid angle area and which diffuses and/or inhibits the scattered particles.

[0024] FIG. 1 shows an arrangement of members of the X-ray generator (one example) of the present invention. In the X-ray generator shown in FIG. 1, a target material (one example of a target member) 101 is disposed in a vacuum container filled with a gas at an appropriate pressure. In the vicinity of a position where a plasma 102 is generated, there is disposed a scattered particle intercepting member 121 which is a member having an opening to pass an exciting energy beam 111 and another opening to pass an X-ray and which intercepts the scattered particles released from the target member 101 and/or the plasma 102.

[0025] Moreover, a scattered particle inhibiting member 122 is disposed adjacent to or in the vicinity of a solid angle area 112 corresponding to a region to extract the X-ray. Furthermore, there is disposed a scattered particle diffusing and inhibiting member 133 which is a member having a movable part 132 capable of passing through the solid angle area and which diffuses and/or inhibits the scattered particles. Here, the scattered particle inhibiting member 122 is a duct-shaped member for

preventing the scattered particles from colliding with or being attached or deposited onto an X-ray extracting window (one example of a clean optical face) 123 disposed in the solid angle area 112. The member is disposed so as to surround the solid angle area 112 and the X-ray extracting window 123.

[0026] Moreover, the scattered particle diffusing and inhibiting member 133 has a shape (blade 232 and shaft 231) shown in FIG. 2. The blade (one example of the movable part) 132 is constituted to rotate using a shaft 131 as a rotary shaft. In the X-ray generator shown in FIG. 1, most of the scattered particles released from the target member 101 and/or the plasma 102 are intercepted by the scattered particle intercepting member 121.

[0027] The scattered particles which have passed through the opening of the intercepting member 121 to enter the scattered particle inhibiting member 122 lose energy while changing travel directions owing to scattering together with buffer gas molecules. The particles are finally mixed into movements of the gas molecules, and float in an inner space of the member 122. Moreover, the scattered particles floating in the space stick to the blade 133 (132) which rotates around the shaft 131 (scattered particle inhibiting effect), or are removed by means of movement of the scattered particle diffusing and inhibiting member 133 (scattered particle diffusing effect). Therefore, a scattered particle density is kept to be low in the inner

space of the inhibiting member 122.

[0028] Moreover, the removed scattered particles are adsorbed by the inhibiting member 122. That is, the above-described functions of the members 122 and 133, or 121, 122, and 133 largely reduce the amount of the scattered particles reaching the X-ray extracting window 103 (123) as compared with a case where these members are not disposed. As described above, according to the X-ray generator of the present invention, even in a case where the plasmas are generated at the short time intervals for the long time, the inconvenient attachment and deposition of the scattered particles are reduced in the X-ray extracting direction. As a result, the device can be stably used for a long time (claims 1, 2).

[0029] In the present invention, the movable part (e.g., blade 132) of the scattered particle diffusing and inhibiting member 133 passes through the solid angle area 112 in which the X-ray is extracted. Therefore, when the movable part is disposed in the solid angle area 112 in a case where the X-ray is generated, the part intercepts the X-ray, thereby lowering the light quantity of the X-ray. Therefore, it is preferable to control a period of an operation (e.g., rotation) of the movable part (e.g., the blade 132) so that the movable part of the scattered particle diffusing and inhibiting member 133 does not exist in the solid angle area 112 when the X-ray is generated.

[0030] For example, the movable part of the member 133

does not have to pass through the solid angle area 112 every time the plasma is generated. The part may pass once in several to several tens of times when the plasmas are generated as long as the density of the scattered particles does not become high in the inner space of the scattered particle inhibiting member 122. It is to be noted that in a case where a certain degree of drop in the X-ray light quantity is acceptable, there may be no correlation between the generation time of the plasma and the movable (e.g., rotatable) period of the member 133. This is because the X-ray in the same area might be constantly intercepted in a case where there is a correlation between the plasma generation time and the movable period of the member 133.

[0031] The influences are further reduced in an application requiring a plurality of times of irradiations with the X-ray as in the X-ray exposure device or the like. In the present invention, the movable part (e.g., the blade 132) of the scattered particle diffusing and inhibiting member 133 can preferably pass through an area (space) as broad as possible in the solid angle area 112 in which the X-ray is extracted in order to improve the scattered particle diffusing and inhibiting effect. For example, the shape shown in FIG. 2 is more preferable than that shown in FIG. 3.

[0032] In the present invention, the introducing and discharging of the buffer gas are preferably controlled so as to bring the inside of the vacuum container into a

predetermined pressure range, so that an appropriate X-ray light quantity or an appropriate scattered particle inhibiting effect is obtained (claim 3). In the present invention, the buffer gas preferably absorbs less X-ray having a wavelength for use (to be extracted). The gas which absorbs less X-ray fro use may be selected from gases such as helium, oxygen, nitrogen, air, argon, and krypton.

[0033] In the X-ray generator of the present invention, a mechanism is preferably further disposed which introduces the buffer gas into the solid angle area in which the X-ray is to be extracted and which discharges the buffer gas together with the scattered particles from the solid angle area (claim 4). According to such constitution, the introduced buffer gas diffuses the scattered particles in the solid angle area in which the X-ray is to be extracted, and the buffer gas can be discharged to the outside together with the diffused scattered particles. Therefore, it is possible to further reduce the inconvenient attachment and deposition of the scattered particles in the X-ray extracting direction.

[0034] In the X-ray generator of the present invention, a scattered particle control member is further disposed which controls a direction distribution of a release amount of the scattered particles released from the target member and/or the plasma and which reduces the release amount of the scattered particles in the direction in which the X-ray is extracted. This is preferable because the scattered

particle inhibiting effect is improved in the X-ray extracting direction (claim 5).

[0035] As a material for use in such scattered particle control member, a material having a high melting point or a high hardness is preferable, such as tantalum, tungsten, diamond, ceramic, or stainless steel. This prevents the release of the member material due to collision of the member surface with ions or electrons flying from the plasma, because the scattered particle control member is disposed in the position very close to the plasma. That is, this prevents the inconvenient attachment and deposition of the released member material in the same manner as in the scattered particles.

[0036] The present invention is preferably further provided with cooling means for cooling the scattered particle inhibiting member, so that the member easily adsorbs the scattered particles, thereby improving the inhibiting effect (claim 6). Alternatively, to easily adsorb the scattered particles, the surface of the scattered particle inhibiting member is preferably worked (e.g., delustering). In the present invention, a shape of the target member is preferably a tape shape which can be wound up, but another shape may be used such as a plate shape, a bulk shape, a columnar shape, or a particulate shape. As a material of the target member, Ta, W or the like is preferable.

[0037] The present invention will be described

hereinafter in more detail in accordance with embodiments, but the present invention is not limited to these embodiments.

[0038]

[Embodiment] FIG. 4 shows a schematic partial constitution diagram of an X-ray generator of the present embodiment in which tape-shaped tantalum is used as a target member and an X-ray having a wavelength of 14 nm is extracted. While YAG laser light (one example of an exciting energy beam) 411 is condensed by a condensing lens 445, the light passes through an incidence window 442 to enter a vacuum container 443, and is condensed on the surface of a tantalum target (one example of a target member) 401.

[0039] The tantalum target 401 has a tape shape having a thickness of 15 μm. A reel 403 is rotated by driving means (e.g., motor, not shown) to wind up the tantalum tape during plasma generation so that the laser light is not repeatedly condensed on the same position of the tape. A movement speed of the tantalum tape is a speed of the movement of the tape by a distance which is not less than a diameter of a hole made in the tantalum tape owing to the plasma generation from a time when one plasma is generated until the laser light is emitted to generate the next plasma.

[0040] The YAG laser is emitted and condensed onto the tantalum tape target 401 at an incidence angle of 45

degrees to generate the plasma 402. The X-ray generated from the plasma is guided into an X-ray optical system from an X-ray extracting window (one example of a clean optical face) 441 disposed in a direction of 45 degrees on a side opposite to the YAG laser. In the vicinity of the plasma 402, there is disposed a scattered particle intercepting member 421 having openings capable of passing the YAG laser 411 entering the target 401 and the extracted X-ray, respectively. Most of the scattered particles released from the target 401 and/or the plasma 402 are intercepted by the scattered particle intercepting member 421.

[0041] Moreover, between the vicinity of the opening for extracting the X-ray and the vicinity of the X-ray extracting window in the scattered particle intercepting member 421, a scattered particle inhibiting member 422 is disposed adjacent to or in the vicinity of a solid angle area 412 corresponding to a region in which the X-ray is extracted. Here, the scattered particle inhibiting member 422 is a duct-shaped member for preventing collision, attachment, or deposition of the scattered particles with respect to the X-ray extracting window 441 disposed in the solid angle area 412. The member is disposed to surround the solid angle area 412 and the X-ray extracting window 441.

[0042] A Kr gas is introduced and discharged as a buffer gas in the vacuum container 443, and controlled so as to retain a pressure of 0.1 Torr. The Kr gas has a

transmittance with respect to the X-ray having a wavelength of 14 nm, the transmittance being substantially equal to that of He under an equal pressure. As to the scattered particles which are not intercepted by the intercepting member 421 and which pass through the opening to enter the scattered particle inhibiting member 422, they lose energy while changing travel directions owing to scattering with buffer gas molecules. They are finally mixed in movements of the gas molecules, and float in an inner space of the member 422.

[0043] Moreover, in a space 444 adjacent to the inner space of the member 422, there is disposed a scattered particle diffusing and inhibiting member 433 which is a member having a blade (one of a movable part) 432 capable of passing through the solid angle area 412 and which diffuses and/or inhibits the scattered particles. The member 433 has a shape shown in FIG. 2, and is provided with a mechanism (not shown) in which the blade 432 rotates around a shaft 431 in vacuum.

[0044] The plasma 402 is repeatedly generated at a frequency of 10 Hz, and the blade 432 of the member 433 rotates around the shaft 431 as a rotary shaft five times per second. The member 433 has two blades 432, and the blade 432 passes through the solid angle area 412 in which the X-ray is extracted from a time when one plasma is generated until the next plasma is generated.

[0045] Here, an oscillation timing of the YAG laser 411

is controlled with a correlation with a position of the blade 432 of the member 433, and controlled so that any plasma is not generated, when the blade 432 is disposed in a position (in the solid angle area) that interrupts the X-ray. When the scattered particles lose energy owing to the scattering with the gas molecules, and float in the inner space of the member 422, they stick to the blade 432 rotating around the shaft 431 (scattered particle inhibiting effect), or they are removed by the rotating blade 432 (scattered particle diffusing effect). Therefore, a scattered particle density is kept to be low in the inner space of the member 422.

[0046] The Kr gas is introduced and discharged in the space 444 provided with the member 433 and the inner space of the scattered particle inhibiting member 422 separately from the whole vacuum container 443. Therefore, the scattered particles removed via the rotating blade 432 are quickly diffused and adsorbed by the inhibiting member 422. Therefore, an amount of the scattered particles reaching the X-ray extracting window 441 remarkably decreases.

[0047] As described above, according to the X-ray generator of the present embodiment, even in a case where the plasmas are generated at short time intervals for a long time, it is possible to reduce inconvenient attachment and deposition of the scattered particles in the X-ray extracting direction. As a result, the device can be used stably for the long time. In the present embodiment, the

member 433 has the shape shown in FIG. 2, and rotates around the shaft five times per second, but the shape and the movement speed are not limited to them.

[0048] Moreover, the number of the blades is not limited to a pair (two blades). As shown in FIG. 5, a scattered particle diffusing and inhibiting member 533 having a plurality of pairs of blades may lower a density of scattered particles in each space where each pair of blades are positioned.

[0049]

[Effect of the Invention] As described above, according to an X-ray generator of the present invention, even when plasmas are generated at short time interval for a long time, it is possible to reduce inconvenient attachment and deposition of scattered particles in an X-ray extracting direction. As a result, the device can be used stably for a long time.

[BRIEF DESCRIPTION OF THE DRAWING]

[FIG. 1] It is a schematic constitution diagram showing members of an X-ray generator (one example) of the present invention.

[FIG. 2] It is a schematic perspective view showing one example of a scattered particle diffusing and inhibiting member in the present invention.

[FIG. 3] It is a schematic perspective view showing an example of an unfavorable shape of the scattered particle diffusing and inhibiting member in the present

invention.

[FIG. 4] It is a schematic constitution diagram showing an X-ray generator of an embodiment.

[FIG. 5] It is a schematic constitution diagram showing an X-ray generator of another embodiment.

[FIG. 6] It is a schematic constitution diagram of a conventional X-ray generator.

[DESCRIPTION OF REFERENCE NUMERALS]

101, 401, 501, 601 target member

102, 402, 502, 602 plasma

111, 411, 511, 611 exciting laser light (one example of an exciting energy beam)

112, 412, 512, 612 solid angle area corresponding to a region to extract X-ray

121, 421, 521, 621 scattered particle intercepting member

122, 422, 522, 622 scattered particle inhibiting member

131, 231, 331, 431, 531 shaft (one example of a constituting element of a scattered particle diffusing and inhibiting member)

132, 232, 332, 432, 532 blade (one example of a movable part of the scattered particle diffusing and inhibiting member)

133, 433, 533 scattered particle diffusing and inhibiting member

123, 441, 541, 641 X-ray extracting window (one example of a clean optical face)

442, 542, 642 incidence window

443, 543, 643 vacuum container

444, 544 space adjacent to an inner space of the scattered particle inhibiting member

445, 545, 645 YAG laser condensing lens

[AMENDED CLAIMS]

[Claim 1] An X-ray generator which uses a buffer gas for forming a target member into a plasma to extract an X-ray and for inhibiting released scattered particles, the X-ray generator comprising:

a scattered particle inhibiting member disposed adjacent to or in the vicinity of a solid angle area corresponding to a region in which the released scattered particles extract the X-ray; and

a scattered particle diffusing and inhibiting member having a movable part capable of passing through the solid angle area.

[Claim 2] The X-ray generator according to claim 1, further comprising:

a scattered particle intercepting member having an opening to pass an exciting energy beam which forms the target member into the plasma and an opening to pass the X-ray and disposed in the vicinity of the target member and the plasma so as to intercept the scattered particles.

[Claim 3] The X-ray generator according to claims 1 and 2, wherein timings of an operation of the scattered particle diffusing and inhibiting member and generation of the X-ray are controlled so that the scattered particle diffusing and inhibiting member does not exist in the solid angle area during the X-ray generation.

[Claim 4] The X-ray generator according to claims 1 to 3, wherein timings of an operation of the scattered particle

diffusing and inhibiting member and generation of the X-ray are controlled so that there is not any correlation between an X-ray generation time and the operation of the scattered particle diffusing and inhibiting member.

[Claim 5] The X-ray generator according to claims 1 to 4, wherein the scattered particle diffusing and inhibiting member has a blade shape, and is structured to be rotatable around a rotation shaft.

[Claim 6] The X-ray generator according to claim 5, further comprising:

a plurality of blade-shaped scattered particle diffusing and inhibiting members.

[Claim 7] The X-ray generator according to claims 1 to 6, wherein introducing and discharging of the buffer gas are controlled so as to bring the inside of the vacuum container into a predetermined range.

[Claim 8] The X-ray generator according to claims 1 to 7, further comprising:

a mechanism which introduces the buffer gas into the solid angle area and which discharges the buffer gas together with the scattered particles from the solid angle area.

[Claim 9] The X-ray generator according to claims 1 to 8, wherein the buffer gas contains one of helium, oxygen, nitrogen, air, argon, and krypton.

[Claim 10] The X-ray generator according to claims 1 to 9, further comprising:

a scattered particle control member which controls a direction distribution of a release amount of the scattered particles released from the target member and/or the plasma and which reduces the release amount of the scattered particles in the direction in which the X-ray is extracted.

[Claim 11] The X-ray generator according to claims 1 to 10, wherein the scattered particle control member is made of a material containing one of tantalum, tungsten, diamond, ceramic, and stainless steel.

[Claim 12] The X-ray generator according to claims 1 to 11, further comprising:

cooling means for cooling the scattered particle inhibiting member.

[Claim 13] The X-ray generator according to claims 1 to 12, wherein at least a part of the surface of the scattered particle inhibiting member is subject to delustering.

[Claim 14] An X-ray exposure device which uses the X-ray generator according to claims 1 to 13 in an X-ray source.